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Research report

The influence of sex information into spoken words: a mismatch negativity (MMN) study

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ABSTRACT

When exposed to a spoken message, a listener takes into account several sources of linguistic and indexical information. Using the mismatch negativity (MMN) response, we examined whether the indexical information about the sex of the speaker influenced the processing of semantically gendered spoken words. Female participants listened two semantically gendered French words, one masculine and one feminine representing human beings, said either by five male or by five female speakers. The opposite sex voices produced an enhancement of MMN response. In line with interactive connections between indexical and linguistic information processing through activating lexical memory traces, the results showed more pronounced MMN response when the sex of the speaker matched with the gender of the word. Furthermore, there was a later detection of the incongruence between the sex information about the speaker and the gender of the word, shown by an enhancement of MMN response. Overall, these findings suggest that the listeners integrate the indexical information about the sex of the speakers both at the lexical selection level and at a higher-level processing such as the grammatical access.

1. Introduction

In daily speech communication, speakers exchange a spoken message with listeners and the sex information can be expressed at three levels, the listener and the speaker, who are biologically sexed, and the sex of the entity represented by the words, categorized by the gender. An intriguing question is to know the interrelation between the three levels of sex information in speech communication (listener, speaker and gender of words). At a very young age, children become aware of their sex and adapt their behaviors according to the role of males and females depending on their own sex by adopting moral values and attribute of members of the sex that they identify as their own. The gender schema theory (Bem, 1983) proposes that children learn to encode and to organize information in terms of an evolving gender schema beyond the simple biological distinction, and they use this information to create the concept of them-selves directly related to the gender role. The specific gender role assumed is mostly reflected by the sex of the listener, and concepts in memory thus strongly differ between sex groups. Additionally, in speech communication, the message received by the listener activates two routes of information processing (Belin et al., 2004, 2011), the indexical information processing coming from the voice acoustic analysis (i.e. information about the sex of the speaker, height, accent, and emotional state) and the linguistic information processing (lexical, grammatical and semantic information about the words). Regarding indexical information, the most important feature to extract the sex of the speaker thanks to the voice is the fundamental frequency (F0). As proposed by the dual-route model (Sumner et al., 2013), the information about the speaker's sex could be integrated in the processing of words at sub-lexical and lexical levels. Moreover, the grammatical gender appears as a need to mark in language the biological sex distinction (Arias Barredo, 1990). Corbett (1991) distinguished two language systems according to how the gender is coded. English, for example, belongs to the semantic gender system in which the gender code is only applied for those linguistic elements having a biological gender referent (brother/sister). On the contrary, the formal gender system, applies the gender distinction to every noun, having or not biological sex referent. Romance languages such as French distinguish between semantically gendered words (when the referent is a biological entity and there is a direct relation between gender and sex distinction, i.e.: frère -brother, *sœur -sister*) and arbitrary gendered words (when there is no direct correspondence between the gender distinction and the sex dimension, i.e.: la voiture -car feminine word, le bateau -boat masculine word).

There have been some attempts to explore the inter-relation between the three levels of sex information. For instance,

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Andonova et al. (2004) designed a behavioral study to explore the influence of the listeners' sex over the processing of gendered words. They used a gender decision task in which female and male listeners had to decide the grammatical gender of a series of words spoken by a female speaker. The results showed facilitation over the selection of the word's gender when there was a match between the sex of the listener and the gender of the word and this facilitatory effect was stronger for female as compared to male listeners. Even though the authors selected both arbitrary and semantically gendered words (281 arbitrary and 105 semantically gendered), an analysis exploring the impact of the different kinds of gender (arbitrary vs. semantically) was not performed. To interpret their main findings, the authors suggested the role of the episodic memory at which the lexical frequency of words would be biased by the sex of the listener, that is, people are more used to hear (in the second and third person) and produce words (in the first person) related to their own gender, and they would pay more attention to this specific set of words. The sex of the listener can also affect the way that listeners process voices of the opposite sex. Indeed, a series of experiments explored the interaction between the sex of the listener and the sex of the speaker by using event-related potentials (ERP) and functional magnetic resonance imaging (fMRI). In particular, Li et al. (2014) performed two ERP experiments to explore the processing of opposite-sex voices compared to same-sex voices regarding the sex of the listener. In the first experiment, participants had to indicate the sex of speakers producing a Chinese monosyllabic word (/hie4/, hey). They found that the ERP amplitude of a positive deflection elicited by the opposite sex voices was stronger than that to the same-sex voices over parieto-occipital recording sites around 750 ms after the voice onset. In their second experiment during which participants had not to pay attention to the sex of the speaker but to a pure tone intercalated among the repeated presentation of the monosyllabic word. In the latter case, no significant ERP differences were found for the opposite sex voices as compared to the same-sex voices. Similarly to the first experiment in the study by Li et al. (2014), Junger et al., (2013) used a task in which participants were asked to indicate the sex of the speakers during the listening of words. By designing a fRMI experiment, they found stronger activation in a fronto-temporal network in response to voices of the opposite sex compared to voices of the same sex.

The information about the sex of the speaker may be accessed almost at the same time as the meaning of the linguistic elements and both kind of information can be integrated at early stages of processing (Lattner and Friederici, 2003; Van Berkum et al., 2008). Furthermore, from the features of voice, such as regional accent, age, social status, and sex, inferences are computed about the linguistic information, leading to modulate the incoming lexical and semantic processing (Brunellière and Soto-Faraco, 2013; Van Berkum et al., 2008). More specifically, in a behavioral study (Vitevitch et al., 2013), it was tested whether the sex of the speaker could influence the grammatical processing. Vitevitch et al. (2013) used a gender decision task during which participants heard masculine and feminine Spanish words. It was required to decide the gender of the word that they had heard. The words were mostly arbitrary gendered (73 arbitrary and 7 semantically gendered) and were said by a male or a female speaker. The results showed that when there was a match between the sex of the speaker and the gender of the word, participants produced faster and more accurate responses than when there was a mismatch between the sex of the speaker and the grammatical gender of the word. It is to be reminded that the majority of the presented words referred to inanimate entities and the gender assignment was not related to sex. They interpreted their results as the acoustic information about the sex of the speaker influencing the processing of high-level information related to the gender feature per se.

It appears thus that the three levels of sex information (listener, speaker and gender of the word) may interact in speech communication. On the one hand, the listener, the person processing the message belongs to either the male or female biological sex group. Their own definition of maleness and femaleness may depend on their own experience (Bem, 1983) and can determine the way people process gender words (Andonova et al., 2004). Besides, the listeners' sex can bias the processing of opposite sex voices (Junger et al., 2013; Li et al., 2014). On the other hand, the information about the sex of the speaker influences the processing of the linguistic information (Van Berkum et al., 2008; Vitevitch et al., 2013), including the grammatical processing of gender. According to the memory traces theory, it is proposed that there are connected assemblies of cortical neurons specified for every word in lexicon in the long-term memory (Pulvermüller et al., 2001; Pulvermüller and Shtyrov, 2006). Such lexical traces are the consequence of the frequent use of words in both perception and production, which links neurons into circuits with strong internal connections through an Hebbian associative learning (Hebb, 1949). Following this theory, the listener may have specific memory traces for the sex concept mostly depending on his own sex group (Bem, 1983), creating a particular and adapted indexical (the sex of the speaker) and linguistic information processing (like, grammatical gender). More exactly, when a person classifies herself into the female group, the memory traces of feminine words would be more strongly connected than the masculine words due to the frequent use of feminine words, leading to a higher activation for feminine words (see, Andonova et al., 2004). Interestingly, three stages are usually described during the spoken-word recognition: initial contact, word selection and word integration (the Cohort model, Marslen-Wilson, 1987). After eliminating the mismatching lexical candidates with the input to obtain the selection of a word, the semantic and syntactic information of the recognized word is mapped onto the contextual information during the word integration. First, during the activation and the selection of lexical candidates, the sex of the speaker could bias the access to the memory traces of words that vary in gender, such that when the information is said by a female speaker the memory traces for the feminine words would be more activated, as compared to the masculine words. In line with some studies showing that inferences driven by the features of voice are computed about the upcoming words (Brunellière and Soto-Faraco, 2013; Van Berkum et al., 2008), we expected a lexical priming effect due to the sex of the voice. Another important aspect to take into account is the interference effect when the mismatch between the sex of the speaker and the gender of the word (Vitevitch et al., 2013) is detected thereafter at higher levels of semantic and grammatical information during word integration. Indeed, when there is mismatch between the sex of the speaker and the gender of the word, the listeners may detect the incongruence between the sex information carried by the voice and the grammatical information present in the word as the gender.

To explore the interaction of the sex of the speaker and the gender of the word through the memory traces in lexicon, we probed the mismatch negativity (MMN) component (Näätänen et al., 1978; Näätänen et al., 2007) by measuring electrical brain activity. The MMN is an indicator of experience-dependent memory traces in the brain. This component is evoked when an unusual stimulus ("deviant") is occasionally presented in a sequence of frequently-occurring stimuli ("standard"). Such paradigm composed of deviant and standard stimuli is called oddball, during which the participants usually perform a passive listening to the stimuli while their attention is focused on a silent movie. Interestingly, Pulvermüller et al. (2001) demonstrated that when a word is presented as a deviant in an oddball design, the representation of this memory trace is active and the brain activity is